The Political Economy of R&D

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Framework of Analysis

Research and development (R&D) performs a crucial dual role in advanced capitalist economies. It serves to generate knowledge and promote the development of new ideas into products, processes and services (called "innovations") that drive economic growth. It can also entrench monopoly power within the large firms that undertake massive R&D spending and then patent or copyright the results. These two roles have become embedded in the modern corporation and form the essence of the political economy of R&D. Both roles are reflected in the work of the first major researcher on innovation, Joseph Schumpeter.

In Schumpeter's first analysis in 1911, he identified the entrepreneurial process in terms of the small capitalist who drives new ideas into the market place while destroying old products and processes ("creative destruction", Schumpeter, 1934), and this seemed to be consistent with the form of capitalism observed by economists through the 19th Century. The innovative activity is seen to be exogenous to the firm (especially the characteristics of the entrepreneur), in what has been referred to as Schumpeter Mark I. At the time, this analysis ignored the nascent rise of the R&D process within corporations instituted by Thomas Edison through his R&D laboratory and factory set up in Memlo Park, New Jersey in 1876. By the early 1940s, Schumpeter recognised the institutionalisation of R&D in sustaining the monopoly power of large corporations to the point that he was concerned that this process would see the end of the entrepreneur as R&D becomes a purely bureaucratic activity (Schumpeter, 1942). This raised the spectre of Schumpeter Mark II with "creative accumulation" from minor incremental innovative activity that is endogenous to the large corporation.

Galbraith (1967) developed further the Schumpeter Mark II analysis by identifying R&D as the endogenous innovation process which attempts to manage the problems of both market and technical uncertainty that emerge out of any new products and processes. In this way the large corporation's "technostructure" sets up strategic planning and related investment commitments in the context of secrecy and intellectual property rights from R&D-generated innovations. Courvisanos (2005a) recognised the interaction of the Mark I and II processes as advanced capitalism moves into the 21st Century, where the small innovative firm complements the R&D process within large firms. Many of the new ideas refined in the R&D process are identified and initially developed by small firms who are closer to the customer and the market place. The large firms set up their R&D through collaborations with, or acquisitions of, small firms.

This paper aims to examine the political economy role of R&D in the context of the innovation dilemma between its role as a knowledge generating processes and the entrenched power that such knowledge creates. Williams (1980, pp. 149-69) provides the analytical framework for this political economy approach by identifying a pattern of three structures within society; *dominant* in which power presently resides, *residual* (or of marginal concern) in which society has overtaken or passed, and *emergent* in which power is being increasingly arrogated. These are overlapping structures that are contingent on the political economic situation in individual countries and their internal regions, as well as the broader global context. After defining R&D, various aspects of R&D will be examined by this triple structure with reference to the innovation dilemma; they are investment, measurement, technological innovation, public policies, globalisation and ethics. The paper concludes with an overview of the patterns of R&D that can be identified using the triple structure.

What is R&D?

R&D is a complete process "…whereby new and improved products, processes, materials, and services are developed and transferred to a plant and/or market. Typically, this process is represented in the firm by a number of formally organized laboratories, departments, groups, teams and functions…most easily recognized…involve scientists and engineers." (Burgelman *et al.,* 1996, p.2) Rosenberg (1982, p. 120) sees this as "a learning process" in the generation of new technical knowledge. The early Edison-type R&D involved purely corporate in-house learning, which all major corporations set up after the Second World War, whether in the form of the ubiquitous laboratory for manufacturing or more diversely as 'new product development' within the marketing department. In the service sector, the locus of learning activities occurs often in groups called 'business development' or 'technology'. Smaller firms also have R&D activities appearing under the titles of 'design' or 'technical support'. All the above require the exchange of information across organisational boundaries *within* the firm, called 'closed innovation' system.

Since the early 1990s, R&D has increasingly involved an 'open innovation' system through distributed innovation processes that leverage knowledge from a broad variety of sources *outside* the firm itself, including university academic research, contracting research from 'centres of excellence', joint venture consortiums, acquired entrepreneurial firms and licensing of innovations. Thus, boundaries for firms conducting R&D have broadened widely under cost pressures and the evolution of the Internet with its supporting web-enabling technologies. "Increasingly firms are acknowledging that it is difficult for them to create and exploit technological innovations on their own." (Bowonder *et al.*, 2005, p. 51)

Research [R] is scientific or technological investigation that has the potential to lead to an idea or concept for innovation. This research is conducted usually by specific experts in two different stages. Basic research is exploratory with no preconceived outcome or direction, and no clearly identified practical applications, but needs to have present or potential interest to the organisation conducting the investigation. This research is associated with scientific discovery or, more generally, knowledge-building. Applied research has preconceived goals based on business imperatives related to specific products, processes or service delivery. This research is problem-solving and needs to take basic research into practical applications that have indefinable private and/or social returns that relate to strategic positioning of the organisation. In an open innovation system, such R involves learning from other technical experts in the variety of sources identified above.

Development [D] explores the specific potential of a product, process or service within an experimental testing environment. This work needs to be conducted at the interface between the technical experts, logistical production managers and marketing departments. Two stages can be identified. First is blueprints development, where a set of designs for specific outcomes are developed from the theoretical research. This is followed by prototype development, which creates test models for technical feasibility (McDaniel, 2002, p. 80). In all stages of D there is need for continual feedback to R in order to improve the theory. This is an iterative process with many failures and dead ends along the way, but is essentially a linear innovation process.

Distinct from the R&D process for this discussion is the related "demonstration" and "promotion" of the innovation, followed by the business investment required to bring forward this innovation into the market place. This is called technological commercialisation and is best described in Jolly (1997). Nevertheless, Jolly (1997, p. 377) notes that all the stages in the commercialisation process need to have significant input and feedback with R&D units. Kline and Rosenberg (1986) call this the "chain-linked model of innovation" that specifically links all the elements of R&D in an evolutionary feedback learning process with all the production and distribution units in the organisation, together with collaborations outside the organisation. "In the end, what companies get out of investments in R&D depends on how they manage different stages of the research process itself, and how they get *other* parts of the organisation to contribute to the innovation process." (Jolly, 1997, p. 363, original emphasis)

Investment in R&D

R&D expenditure is often referred to as spending, yet conceptually the funds allocated to R&D should be recognised as investment in the future in the same way as investment in plant and equipment. Even failed R&D projects contribute to the corpus of knowledge by identifying what does not work and creates further problems to be solved with further investigations. Basic research is the most creative stage of R&D investment, with the "…more intractable the problem, the more one is curious about it." (Jolly, 1997, p.375) In this way, R&D spending is a significant part of what economists now call "intangible investment" because it is an investment into future production but the knowledge-base that such investment creates is not tangible and obvious as plant and equipment (capital) investment (Webster, 1999).

All forms of investment need to be evaluated on the basis of rates of return to be obtained in the future. The future is uncertainty, so any calculation of future returns is subject to imprecision. With capital investments on known products or processes, there are standard forecast techniques for calculation of rates of return. R&D is aimed at generating something new that was previously unknown or not present. Given the complexities involved in this process, the outcomes of R&D investment are subject to fundamental uncertainty with no probability distributions available, such that standard forecast techniques are inappropriate (Davidson, 1991).

Fundamental uncertainty is evident when the elements of R&D investment are broken down into their component parts. The various stages of R&D identified above all have different outputs, each one is difficult to evaluate and has diverse possible outcomes. Thus, evaluation depends on the judgement of experts at the various R&D stages. However, Mansfield *et al.* (1972) in a classic study identified that these experts tend (when they are planning) to greatly underestimate development costs, while they greatly overestimate the time taken to produce results. Then, Tidd *et al.* (2005, p. 218) noted that scientists and engineers in basic and applied 'R' are often deliberately overoptimistic in their estimates in order to give the illusion of a high rate of return to conservative accountants and managers. As a result, R&D management requires a much more effective communication between R&D staff and the persons responsible for allocation of financial resources, as well as seeking outside advice on the management of the R&D portfolio (Ettlie, 2000, p. 149).

The Mansfield study of project selection in large US firms, comparing forecasts to outcomes found that the probability of picking winners by the technostructures in these firms was only 16 per cent. Jolly (1997), 25 years later, confirms that the Mansfield results still stand even with the advances in modern computer technology. Thus, despite attempts to manage market and technical uncertainty, the technostructure generally fails. This leads large firms to protect any successful innovations in order to maximise returns over as long a period as possible. Such protection can be legal (like secrecy and patents) and illegal (like cartel arrangements), creating monopoly power for that period of protection.[1] This role of the technostructure can be identified as the dominant structure attempting to quell any possible emerging threats.

Measurement of R & D

R&D is measured in three ways; input, output and capacity. From the process context there is a set of input measures of R&D, notably: R&D expenditure (or spending) in absolute monetary figures, R&D intensity as a ratio of R&D expenditure to sales turnover, number of R&D employees, and technological capability in terms of R&D stock. R&D expenditure is a common *absolute* measure of financial commitment, while R&D intensity takes this spending figure and provides a *relative* measure in relation to sales. Employee numbers gives some notion of human resource capability, while technological capability is better measured by the R&D stock built up in the organisation. Dominant and residual structures residing in large manufacturing sectors like automobiles and electronics are strongly represented in the absolute input measure, while rising industries like biotechnology are represented strongly in the relative input measure.

For the output of creative and intellectual effort, there is a different set of R&D measures. Most common in marketing terms is the number of sales of new (up to 5 years after launch) products relative to total annual sales. R&D productivity measured by income from new products relative to R&D expenditure (lagged 3-5 years) is a favourite of the accountants who allocate R&D funds. From a more technical perspective there is R&D output intensity measured by the number of patent applications to real (deflated) R&D investment. At a purely scientific level, there is the number of scientific articles published in quality science journals and the extent that these articles are cited over the following few years. Finally, technology licences issued to other firms is an indication of the extent of diffusion of the R&D innovation, but this is generally viable as a measure only where the technology can be easily 'unbundled' and adopted by other firms with different institutions and culture.

Building technological capacity for effective R&D can also be measured, but by more qualitative indicators from inside and outside the firm. Internal indicators identify the extent of technical expertise, focus on end-user needs, cross-functional and fluid

[1] For example, in June 2004 the US Congress extended copyright on music from 50 to 95 years in order to protect the commercial interests of recorded popular 'rock' music (the Sonny Bono amendment). This date was *not* coincidently one month before the first major 'rock' recording, Elvis Presley's "That's All Right Mama", was about to run out of copyright since it was released on the 19th July 1954 (*The Sunday Age*, 2004).

research teams, strategic focus and formal development processes (see Menke, 1997). External indicators identify specific capacity-building R&D structures; especially lead user groups (see von Hippel, 2005), innovation networks, research consortia, strategic alliances and joint ventures related to market developments (see Tidd *et al.,* 2005, pp. 296-315). These R&D activities can be identified with the emergent structures in areas like pharmaceuticals and telecommunications arising chiefly out of the growth of external sources of R&D under the distributed innovation process (Bowonder, 2005, pp. 51-2).

The most difficult to measure is R&D done *not* under the banner of 'R&D'. Particularly, this is the case in two areas. One is 'informal R&D' undertaken in less organised and *ad hoc* basis (e.g. trouble shooting on the production line). In many countries, especially large ones, informal R&D is regarded as too difficult to survey (Pavitt, 1994), whereas some small countries like Australia survey all size firms for all forms of R&D (Bryant, 1998, p.59 fn.4). The other is service-based and some product-based efforts in innovation which use electronic information technology for investigation and testing. Rosenberg (1982, p. 191) identified this problem a long time ago when he said: "Software development shares many of the problems of any R&D activity." Freeman (1994) noted the rise of information technology as an area of innovation itself did not come out of identifiable R&D activities. Bowonder *et al.* (2002) identify the emergence of e-engineering and e-design for innovation as central to R&D but not measured in current R&D metrics.

R & D and Technological Innovation

There is a major debate over the issue of R&D as the source of significant technological innovation. Source of creativity by R&D is a two-edged sword for the technostructure. The technology imperative demands from the technostructure two conflicting actions. It needs to maximise the gains from any successful innovation developed in-house, while focusing on radical innovations for a distinctive competitive edge. Tension exists between the two scenarios for R&D, incremental or radical innovation: Incremental represents minor improvements on existing products or processes that require little organisational change, while radical innovation represents revolutionary departure from current operations with significantly different skills and capabilities.

On the one side there is the recognition that incremental innovation provides 'extra' profits from successfully introduced radical innovations with only marginal R&D input. Financial managers encourage incremental innovation, since it can be calibrated easier with simple 'rules-of-thumb' for allocating resources, establishing sunset criteria for projects and using sensitivity analysis based on a known range of assumptions while reducing key uncertainties before commitment (Tidd *et al.*, 2005, pp. 218-20). This is an organisational constraint where financial shackles stymies innovative edge as financial controllers seek short-term gains. Chiesa (2001) in his guide to R&D management argues for commitment of funds for R&D in the incremental innovations of existing corporate technologies. New technological opportunities require difficult overall corporate strategic planning changes that need first to overcome organisational constraints by realigning a firm's strategic plan to some core technological focus. For example, are automobile manufacturers in the business of individual people movers or the petrol-driven vehicles? The latter limits their strategic focus to a narrow technological focus with only incremental innovation possible.

This ‘incrementalism’ is further entrenched by marketing efforts and monopoly power. Professional R&D executives recognise the role of marketing in its interaction with lead users of the products in setting the R&D agendas. This is done not only by standard marketing ‘research’ surveys, but increasingly more prevalent has become collaboration with lead users on finding what such users ‘need’ to improve use of their products, e.g. mountain bikes and computer software (von Hippel, 2005). Monopoly power of secrecy and property rights aim to stifle radical innovation being conducted by smaller entrepreneurial firms or even in-house radical ideas which threaten the current strong market position of the dominant firm(s). Lessig (2004) has argued this case very persuasively with strong empirical evidence from the media industry. For example, RCA squashed all attempts by their R&D engineer, Edwin Armstrong, to introduce the higher quality FM radio band; all RCA wanted was to protect their monopoly of the AM band by reducing the static noise on the AM band (Lessig, 2004, pp. 3-7).

On the other side, there is evidence that radical innovations are significantly more likely to be commercially successful (Ettlie and Rubenstein, 1987). This is because the accumulated firm-specific intangible knowledge for future opportunities (first mover advantage) tends to be greater the more radical the innovation. The difficulty is assessing which ideas will eventually succeed and having to pursue many on the expectations that one will succeed. There is no probability distribution and thus no calculable risk assessment that can be made for successful radical innovations. Ettlie (2000, p. 40) estimates that only 6-10 per cent of all new successful products are radical, while successful radical processes are even scarcer. Also, radical processes tend to follow radical products with a lag, but then both technologies become entrenched and lose their ‘cutting edge’ (Abernathy and Utterback, 1978). Focusing on radical innovations will not only require a considerable shift in skill capability and organisational structure, but it also introduces the threat of new entrants (some very large with ‘deep pockets’) into the industry who are prepared to diffuse the innovation. Concentration on radical R&D requires brave foresight on the part of established business.

Up to the early 1960s R&D was funded directly from central corporate sources. This has become a residual structure as there arose a growing movement to fund from contracts between the R&D division and other internal and external business ‘groups’. For example, Philips (with 5 labs around the world) began in 1990 to have its funding from head office reduced to one-third, with the remainder coming from contracts from business groups (Jolly, 1997, p. 346). This trend threatens creative R&D in radical innovations and tends to support incremental innovation driven by contract-based strategic marketing needs. Philips, realising this, modified their funding structure in 1994, requiring roughly half of the two-thirds controlled by business groups to be “…devoted to immediate product development; the remaining half has to be for longer-term capability development in certain technology clusters, such as signal processing for TVs. Typically, this part is funded by more than one business group as well.” (Jolly, 1997, p. 349) This is the nub of the dilemma, determining how R&D strategies address both short-term market-based needs and long-term knowledge-accumulation needs. This all depends on the valuation of strategic intent by the firm undertaking R&D.

The valuation of strategic intent is influenced by two factors. One is the life-cycle of the current radical innovation. During the early stages of a successful innovation, incremental changes out of R&D result in substantial gains for the firm and in terms of social benefit as the innovation is adapted and diffused. Then as the innovation matures, R&D tends to suffer diminishing returns in terms of new knowledge and new applications. At this mature stage defensive R&D efforts aim to maintain market position (Bar, 2006). The other factor is the size of the firm. Ettlie and Rubenstein (1987) examined 348 US manufacturing firms and identified smaller firms (up to 1,000 employees) as introducing at the same rate both radical and incremental new products, then as firms increase their size up to 11,000 employees their greater size tends to promote more radicalness. When firms become very large (greater than 11,000 employees) and the technostructure becomes powerful, there is a clear lack of radical product innovation despite often very large R&D units.

R & D Public Policies

Central to all nations' industrial and innovation public policy strategy is the approach government's take to funding and supporting R&D. Gerschenkron (1962) associates such strategy with the 'late' industrial development stage of the global economy. The economics literature has identified four rationales for such emphasis on supporting what is essentially a private sector activity. The first is the neoclassical supply-oriented competition concerns arising from 'market failure', developed most notably by Arrow (1962). This argument is based on inadequate return for the private sector in R&D due to few and uncertain pay-offs from basic research. As noted, large firm R&D tends to support incrementalism, because there is limited market-based encouragement for more uncertain new technologies in less powerful industries and firms where the scale of R&D is too low to generate the critical mass of new knowledge. Also, duplication by competitors tends to quickly undermine any competitive edge established by the initiator (free rider issue). From the nation's standpoint, these problems of market failure lead to underinvestment in R&D.

The second rationale centres on national security issues developed by Gansler (1980). Ability to be self-sufficient in circumstances of secrecy on defence (and space program) strategies drives this concern (offensive). It is bolstered by concerns of being cut-off or refusal to trade during military conflicts (defensive). R&D spending, due to secrecy and lack of direct civilian applicability, can not be supported in private markets. This R&D is financed by the public sector, but developed in the private sector, with the use of procurements to drive down R&D costs. In the long-run the knowledge gained provides a platform for new civilian capabilities far into the future (e.g. computers, GPS, commercial space travel). This has been the case throughout history, but clearly at different rates of civilian uptake (White, 2005).

The third rationale is based on evolutionary economics, centred on a systems approach that rejects the linear model of R&D. The national innovation system is a set of institutions whose complex interaction via clusters, collaborations and networks across the public-private sector space determine the extent of innovative performance (Nelson, 1992). In this system, R&D forms the foundation of knowledge and its applicability for innovation. However, systemic failures in private sector R&D due to lock-in, transitional problems, poor knowledge-based infrastructure, and inappropriate conventions and institutions justify the need for national governments to overcome these failures in a strategic way (Smith, 1998). For example, private sector R&D support for small firms with single innovation ideas are hard to justify on financial grounds because the chances of success before any patents expire are very low (Legge and Hindle, 2004, p. 337).

The final rationale is based on environmental concerns. Exhaustion of non-renewable resources and pollution threaten the environment's ecosystem viability, while markets do not reflect the ecological value of sustainability of human and other life on this planet. Thus, there is a need for public finance and support of R&D on decentralised alternative new energy sources and reducing pollution (McDaniel, 2002, p.85). Neoclassical and evolutionary economists could claim this argument for their respective market or systemic failure arguments, however ecological economists see the ecosystem overriding both such approaches. A market failure approach can merely encourage the public support of R&D into costly and unsustainable 'end-of-pipe' technological solutions. A systemic failure approach to work from this environmental perspective needs R&D that has clear ecological directions and rules that allow for adaptation and incremental change towards a decentralised sustainable ecosystem (rather than support, for example, of massive centralised nuclear power and corporate genetic engineering, see Skea, 1994).

Two types of R&D public policies are possible, passive and active (Legge and Hindle, 2004, pp.237-50). Passive policies respect *laissez-faire* market solutions by attempting to override market failures, giving markets a better chance to work effectively. This would involve intellectual property rights (IPRs) protection of R&D innovation to overcome the free rider issue, and providing broad R&D rebates, subsidies and incentives in order to reduce risk and support scale economies. This is the neoclassical approach to R&D public policies. Cannon (2005) explains that the USA, as the leader in R&D, has strong preference for passive R&D policies and notes the four successful R&D instruments are (in order of importance): tax relief, defence support, patent protection, and college education. The paradox of passivity by not picking winners and yet supporting massive defence R&D does not seem to be apparent in Cannon's analysis, but this is to be expected from the perspective of the dominant structure that inhabits R&D in the USA. A more recent variation of this neoclassical "passive" approach has been policies to shift R&D support from large corporations towards small business (through programs for technology start-up companies like pre-seed funding and incubators). Though the conservatives could suggest this change is due to market failure as large corporations override the market, such a *post hoc* rationale undermines the whole passive approach and leads directly to active policies.

Active policies aim to directly intervene in order to influence the direction and extent of R&D innovation. Sectoral R&D assistance to specific industries aims to address concerns of the lack of innovation in this area (e.g. CSIRO as the Australian public research body in support essentially of the agricultural sector). Selective public investment in research infrastructure (e.g. synchrotrons, technology parks, cooperative university-business research centres), subsidies in specific areas of concern (environment, social groups, non-urban regions) and public sector procurement of R&D (as in defence industry) all provide direction as part of public policy support.

All rationales bar neoclassical tend to support such active policies, with the particular direction of R&D support up for debate at the political level (centralised authority or democratic grassroots). The proponents of such active policies argue on the basis that these are emergent structures which will eventually dominant.

In reality, R&D public policies end up being a mix of both passive and active, depending on the political trajectory that a nation has traversed over the last fifty years. The trend of R&D policies will reflect the rationale which is being championed by the political powers at the time. There are, however, some theoretical limitations to R&D support by the state. In relation to subsidy/incentive-type support, successful R&D innovations end up benefiting the private sector firm involved twice, once from financial support and second from profits of the innovation often with state-endorsed monopoly control through IPRs. Concern also exists as producers of R&D get exclusive benefits of the IPRs, when often it is users who generate the innovative ideas but all benefits go to producer who also gets patent (and other) IPR protection (see von Hippel, 2005).[2]

Questions are also raised about governments' attempts to 'boost' R&D when it is used merely as a marketing tool for incremental innovation (How many blades can you place on razor shaver?). This is supported by evidence that incumbent enterprises, with minor innovative activity, benefit most from such R&D public support during long economic expansions; whereas new firm start-ups are triggered by economic contraction and unemployment supported by university research in particular (Audretsch and Acs, 1994). At the other extreme with radical innovation, there is the growing neo-liberal influence in many western economies to encourage support for small-based entrepreneurial start-ups based on some "…exaggerated claims of their role in innovation" (Legge and Hindle, 2004, p. 247), when in fact the vast majority of entrepreneurial start-ups are extensions of work conducted prior to start-up (Bhidé, 2000). Further, Åsterbo (2003) shows evidence of unrealistic optimism in a sample of 1,091 independent inventions, with only between 7-9% reaching the market and 60% of them obtaining negative returns.[3]

Empirical evidence on R&D support is mixed. Bloom *et al.* (2002) draws the conclusion from a nine major OECD-country study that generally R&D tax credits have had a significant effect. However, other studies have found several problems with this form of incentive: applies to only new R&D, criteria are stringent, no distinction between R&D spending and success rates, productivity effects are varied, and ignoring the increasingly important role of collaborations (Ettlie, 2000, pp. 298-300). Active policies like selective investment (e.g. energy), incubators and technology parks have had varying success, depending on how well targeted the policy is, how well it is administered and monitored; then there is the level of synergy of companies involved with similar and complementary endowments. Finally there is the motivation of the participants themselves in these research infrastructures.

[2] The problem of IPRs "…being hijacked by larger firms, particularly for strategic purposes" is a public policy concern addressed by Dolfsma (2006, p.339).

[3] Audretsch (1995, p. 122) places the above discussion into the US context by stating that "…although divergences in beliefs regarding (potential) innovations may induce a greater amount of startup activity, the likelihood of any new firm actually surviving and having a substantial impact on the industry is relatively low. Thus we observe a relatively high number of entrepreneurial or young firms, whose impact is, on average, relatively negligible."

Australia has been notable for selective investment in two major successful innovation-based research infrastructures: CSIRO and AIS (Australian Institute of Sport). Both have been models that have been studied and copied around the world, however, Australia's natural and cultural endowment in agriculture and sport have much to do with this success (Fox, 2001).

A third of OECD countries (all small economies) have public as their major source of R&D funding, also all less developed economies depend on government for R&D. From this it can be noted that higher education and government sectors perform almost 30 per cent of all R&D (OECD, 2005).

Thus, the track record for active policies is mixed. If in concert with major security concerns, the military rationale will be successful. The other two active-based rationales have had mixed results, with proponents pointing to countries like The Netherlands who have been able to develop innovation policies for sustainable development. Such success has only been achieved on the back of major environmental crisis that the population as a whole comes to accept (Courvisanos, 2005b).

Globalisation of R & D

R&D spending is gradually globalising in concert with general business globalisation, but not in a straight direct transfer of operations. The form it is taking provides massive potential opportunities for democratising the innovation process and reducing the dominant structure of the institutionalisation of R&D described above.

The evidence, based on country of origin in front page patent citing and company R&D spending data, is quite clear that the majority of R&D by global corporations occurs in their home of origin. Only 12 per cent of the world's large firms conduct R&D outside their home country, compared to around 25 per cent equivalent share of production. Notably, on average foreign-based production is less innovation-intensive than home production, with firms from smaller countries generally having higher shares of foreign innovative activities. Most R&D performed outside home sites occurs in USA and Germany, with a growing trend in biotechnology and IT for European firms to conduct R&D in USA so as to access local skills and knowledge (Tidd *et al.*, 2005, pp. 211-13). Meyer-Krahmer and Reger (1999) characterise R&D as being in the dominant "Triadization" structure, involving companies from the USA, the EU and Japan. OECD (2005) figures indicate at the broader level of 30 leading economies (excluding China and India), that well over 16 per cent of total R&D expenditure is performed abroad by foreign affiliates. The picture that emerges is a complex mosaic of rising internationalisation of R&D but with limited "techno-globalism".

Domestic country of origin R&D stills matters to large corporations. Tidd *et al.* (2005, pp. 213-16) have identified reasons for this: When launching substantially complex new products and processes, there are major efficiency gains from close proximity to R&D developments for knowledge integration and dealing with unforseen problems. Despite IT linkages, tacit knowledge through close personal contact matters. There are very high fixed costs in setting up such R&D infrastructure outside of the domestic country or region where R&D originally developed and thus created a strong culture and technological trajectory. Spread of R&D depends on the ability of industries to overcome these inherent domestic advantages. Compare the automobile industry's need for some geographically-based R&D (cars for Australian conditions is different to Europe and USA) with pharmaceuticals need to be close to basic research knowledge from particular knowledge-intensive centres (e.g. universities with pharmaceutical research expertise). Matching foreign localisation with highly specialised R&D personnel can be difficult and requires significant ability in mobilising such staff. Thus, R&D works best at foreign centres with more established products and services that have moved considerably down the life-cycle for market-seeking ('capability exploiting', CBE) motives, while embryonic ones stay at home. Despite China's strong economic growth at the beginning of the 21st Century, R&D is essentially only at this CBE level (Dahlman and Aubert, 2001, pp. 121-38), with an R&D intensity of seven times less than the OECD average (Gilboy, 2004).

In attempts to overcome limitations of R&D direct globalisation, outsourcing and collaborative R&D on a more global basis have become a strong trend. The agency for this move has been the development of global knowledge networks across the private-public sector space for resource-seeking motives. Scientists and engineers were the first to develop electronic-based global knowledge networks in military, space and then university research, all public sector funded. More recently, business firms have found it very useful to tap into these existing knowledge networks and to extend them further in what Kuemmerle (1997) calls "capability augmenting" (CBA) R&D facilities close to centres of research excellence that these companies are able to tap into. European firms tend to follow this CBA approach strongly, with Ambos (2005) providing evidence to support this with respect to 134 R&D laboratories of top German global firms. These networks link researchers in advanced economies, leaving the rest of the world outside these networks.

Outsourcing of non-core R&D activities in incremental innovation has been the major form of internationalisation with the links being vertical to suppliers and customers (especially lead users) throughout their extended global value chain. Examples of such outsourcing partners who can reduce transaction costs are systems integrators, technology consultants as well as more traditional suppliers (inputs) and customers (marketing). Increased global sourcing and marketing has allowed for more extensive and flexible outsourcing arrangements, with loose coupling of multi-technology products allowing for uneven rates of advance to be accommodated up and down the value chain (Brusconi *et al.*, 2002).

An extensive literature in collaborative R&D identifies a variety of forms, from "simple" joint firm cooperation, to competitors R&D consortia, to virtual (electronic) collaborations (see Ettlie, 2000, pp. 159-69 for detailed discussion). They tend to be associated by way of horizontal links with competitors and work better when stimulated to join for reasons such as start-up phase, threat of new entries, or concern that maturity has set in. Small innovative firms provide strong synergistic support for large firms, with small firms acquiring market knowledge and financial support while large firms acquire new technology. Collaborations are increasingly more flexible such as strategic alliances (rather than joint ventures) and they are based around universities, technology parks, and private consortia. Almost all of the 80 per cent growth in technology collaborations since the mid-1980s is accounted for by the high technology areas of pharmaceuticals, biotechnology and ICT who are particularly keen to establish flexible collaborations to allow for technology switching. Aerospace and defence actually have declined their collaborative R&D efforts over the same period (Tidd *et al.*, 2005, pp. 318-9).

The above globalisation forces are providing opportunities for a broader group of countries, experts and groups to become involved in the R&D process in a more democratic way. Strongly developing economies with rising technological expertise are being seen as potential by large global firms for access of science and technology resources (human and capital) at significantly cheaper cost (Reddy, 1997). For countries like India, China and South Korea, this provides an opportunity to integrate into global technology systems, but the terms of engagement need to be carefully balanced to ensure favourable outcomes for these nations.[4] There are also opportunities for environmental groups, aid agencies and specific scientific communities to become involved in the global knowledge network, not only from the greater involvement of lead users championed by von Hippel (2005), but also from collaborative and outsourcing arrangements that could influence the development of innovation in large corporations over the next century. These are emergent structures that need support from governments that can establish active public policies to encourage such initiatives. Neo-liberal passive public policies will merely lead to R&D being dominated by the needs of global corporations, leaving these more democratic processes of innovation only as residual structures in the R&D global system.

Ethical Issues

The final area of political economy of R&D to be examined is ethics. Ethics is an important issue in R&D that has in the past been ignored by the dominant structures within the scientific and business R&D communities in their technology-push mentality that all research and new knowledge is inherently 'good'. Philosophers and ethists like Peter Singer who have questioned this inherent goodness have been seen as 'cranks' allowed voicing their minority view in a democracy. In the 21st Century, with R&D biotechnology enabling the alteration of human genetics, the ethical issues of R&D have been rammed into the front of the R&D community. There are now thousands of patents worldwide (except in France) on the human genome, with a global alliance human genome project aimed to increase this number dramatically. The ethics and economics of such R&D are in conflict, and the low standards in modern business ethics (as for example drug trials in India) indicate that corporate decision-making will not produce the philosophically desirable outcome. Survival of businesses and research staff may not be the best way of ensuring the considered long-term implications of altering the world's gene pool and the ecosystem (see Flowers, 1998).

Patterns of R&D

The dominant structures in R&D are national security concerns and the role of large corporations in incrementalism. National security concerns shape innovations systems and particularly the R&D component. With national security concerns raised even higher after the collapse of the World Trade Centre on 11 September 2001, *a priori* there would seem to be even greater publicly funded support for defence/security

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[4] Unfortunately, the skill base and political regimes in Africa are not conducive to becoming part of any such potential emergent R&D structure. Latin America has some potential, especially in Brazil where the government is supporting the development of a strong generic pharmaceutical industry to the frustration of the major global pharmaceutical firms (Cohen, 2000).

based R&D across all economies, but dominated by the USA and UK as they lead the anti-terrorism strategy. As well, the monopoly power of large corporations to dominate R&D in marketing-based incremental innovation remains. Both structures will continue to dominate R&D well into the future.

Residual R&D structures that remain, but are increasingly less relevant, relate purely to in-house based creativity and development projects along with capability exploiting foreign-based R&D activities in cheaper developing economies where there is some strong R&D-based skills. India, for example, has a strong medical training tradition which is now being used by the major pharmaceutical companies to assist in undertaking R&D drug trials, but with much reduced ethical standards that have enraged civil rights defenders.

Emergent R&D structures are centred on services-based areas of knowledge, much of it not conducted in official R&D centres. Firms in the new economies of India and China are emerging out of technology transfer into their own capability augmenting R&D often in concert with collaborative firm partners from established R&D strong economies. This provides only a very limited globalisation trend in respect to R&D. Lead users and other democratising elements of R&D activities are becoming more established in western economies, providing opportunities for a broader constituency in developing innovation and challenging the dominant incrementalism. This involves more public policy input into the creativity and commercialisation aspects of R&D as well as greater public debate on the ethics and global impacts of R&D. From this there needs to emerge a broader collaborative R&D innovation process that includes alliances and network sharing across a large and diverse range of communities interested and affected by R&D development; from conservation groups and trade union bodies, to scientists, corporate leaders and entrepreneurs. Emergent structures find it difficult to survive and grow in the face of opposing dominant structures of ‘vertical’ based specialist silos of knowledge.

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